Some basics re Liquid Argon Purity:

Liquid Argon TPCs work by detecting electrons liberated by passage of charged particles and drifted under an electric field to sense planes.

The argon is the target (ie the material where the interactions happen) and the detection medium (ie where the detectable aspects of the interaction – ionization and light - are produced)

The sense planes are (typically) immersed in the liquid argon.

For the device to work, the electrons must travel from their point of ionization to the sense-planes – typically 1 to a few meters. (Distance set by argon purity, high voltage)

Achieving and maintaining adequate purity is one of many challenging aspects for a successful TPC.

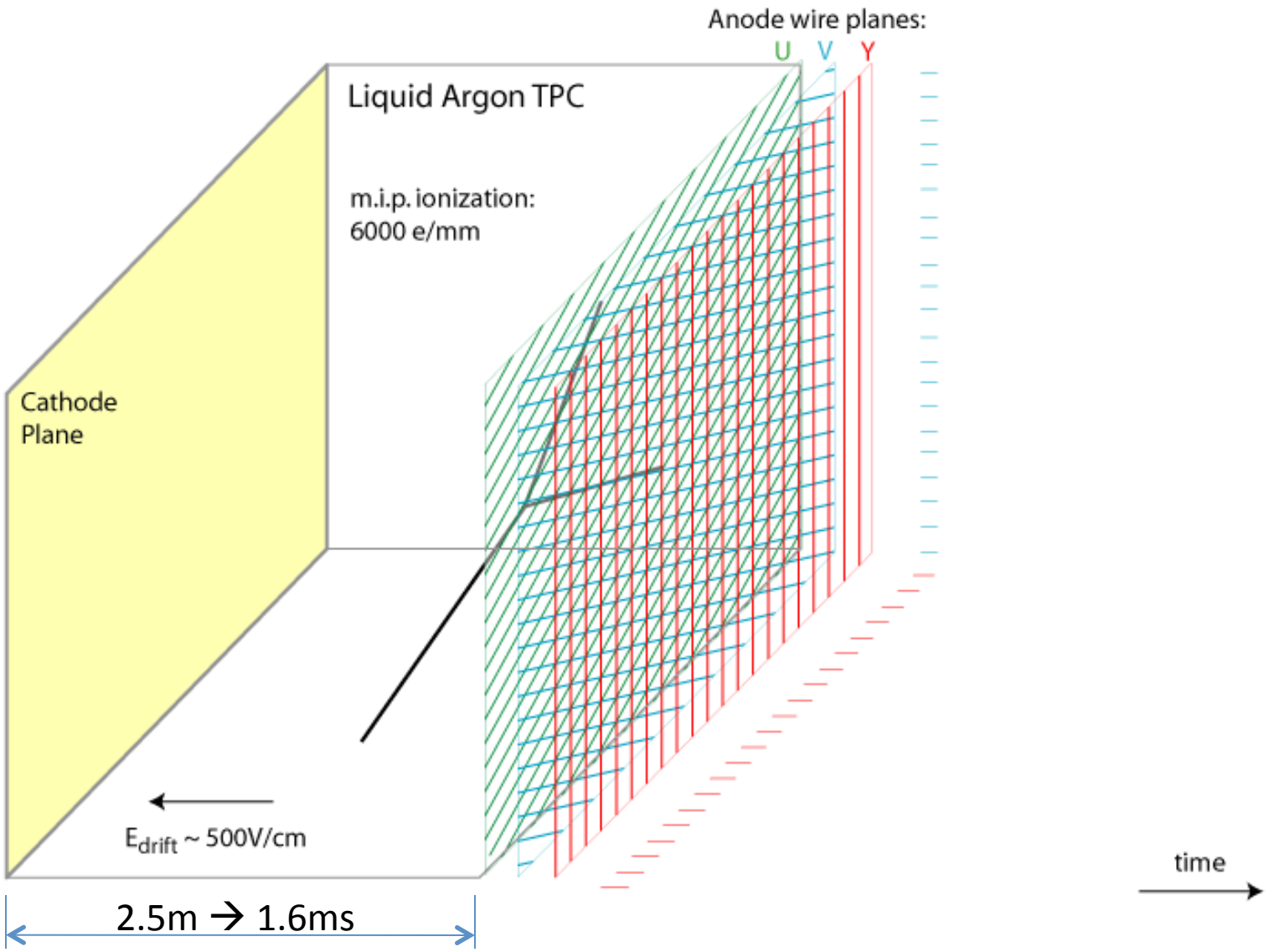
Documentation for new people:

A system to test the effects of materials on the electron drift lifetime in liquid argon and observations on the effect of water. FERMILAB-PUB-09-355-E, Jul 2009

lartpc-docdb.fnal.gov lots and lots of stuff from POs for filter material to schematics
username lartpc

microboone-docdb.fnal.gov microboone specific stuff
username uboone

projects-docdb.fnal.gov T962 (ArgoNeuT stuff)
username T962



Need extremely good LAr purity, low convective flow

Free electrons can survive effectively infinite time in pure liquid argon (basic assumption).

They are `lost' by capture on electro-negative molecules – oxygen and water. (The -ve ion continue to drift towards the anode (+ve electrode) but at 1/100,000 the speed and contributes no signal.)

Parameter used to describe purity is `electron drift lifetime' – sometimes just `lifetime'

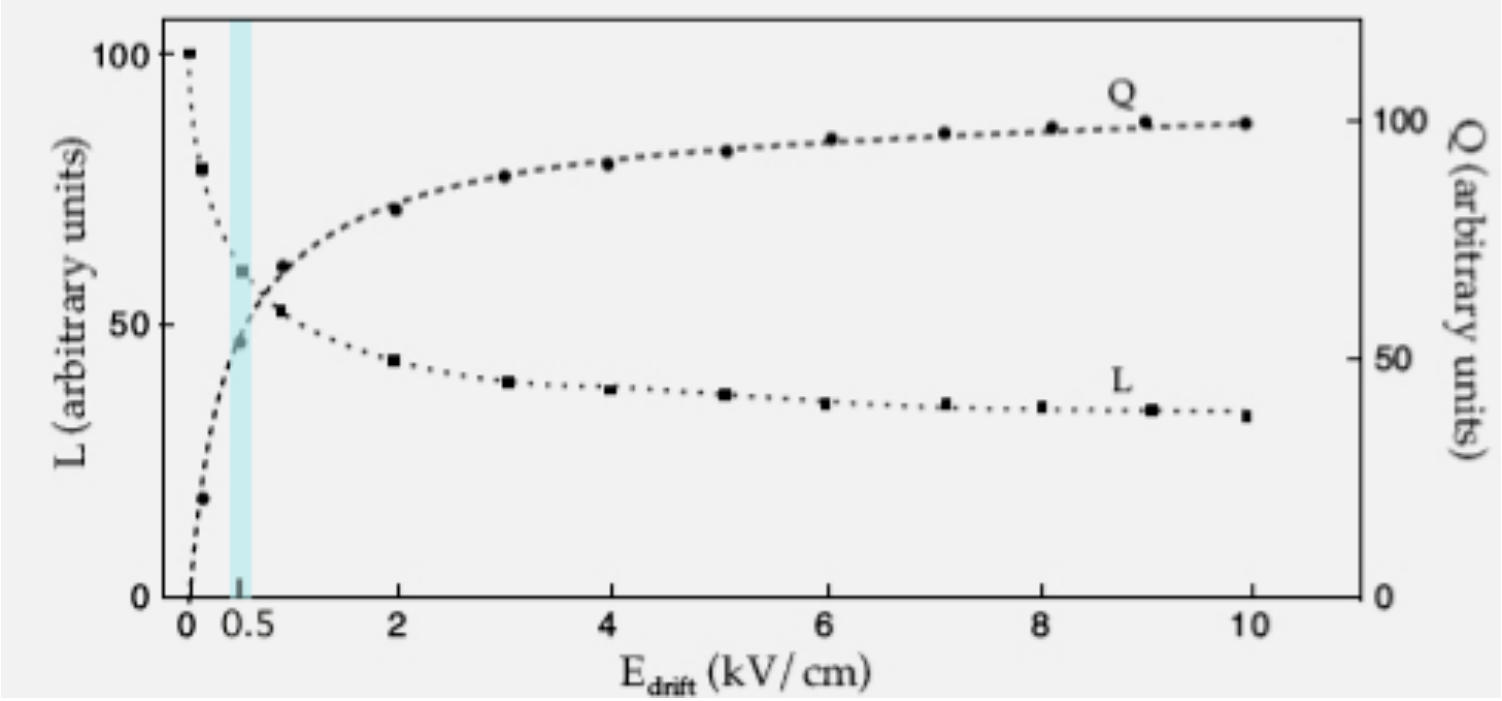
Note `lifetime', not distance of travel, is the important parameter. The capture probability is proportional to:

the number of collisions between an electron and the atoms/molecules of the liquid on its merry way from its parent argon atom where it was ionized to the sense plane X *the fraction of the collisions which involve a water or oxygen atom.*

Longer time -> more collisions, higher probability of capture
More impurities -> higher probability of capture

Longer distance between cathode & anode
=> more mass for same number of readout channels (good)
=> higher voltage between cathode and anode (hard)
=> and/or longer electron drift-lifetime (our job)

Light and free charge output depend on electric field – not a free parameter;
lower field => more recombination (less free charge) and more light
higher field => less recomination (more free charge) and less light



Set a scale:

Typical `drift velocities' are 1 meter to 2 meters / millisecond: (E = 22kV/m to 90 kV/m)

Fact:

1 part per billion (ppb) oxygen is lifetime of 0.3 milliseconds=>
100 parts per trillion = 3 ms, 30 parts per trillion = 10 ms etc

Commercial Argon at Fermilab is spec'd at 5 ppm oxygen;
in practice dewars are usually below 0.5 ppm (but not always)

Need to go from ~ ppm to 30 ppt oxygen;

AND DON'T FORGET WATER.. AND LET ME ADMIT IMMEDIATELY:
I DON'T HAVE EQUIVALENT NUMBERS FOR WATER CONCENTRATION & LIFETIME;
WHAT INDICATIONS WE HAVE SUGGEST WATER IS WORSE THAN OXYGEN

The development of liquid argon TPC technology comes from the ICARUS collaboration as expressed in the so-called T-600, two 300 ton LArTPCs completed in 2000 and now being commissioned at Gran Sasso in the CERN long base-line beam

We asked (in 2005) what could we do that was relevant and new.

⇒ understand the purity issues associated with a cryostat that cannot be evacuated as would probably be used in a multi-kiloton device.
⇒ characterize effect on the drift-lifetime of materials for use in a detector in a cryostat that was not evacuated

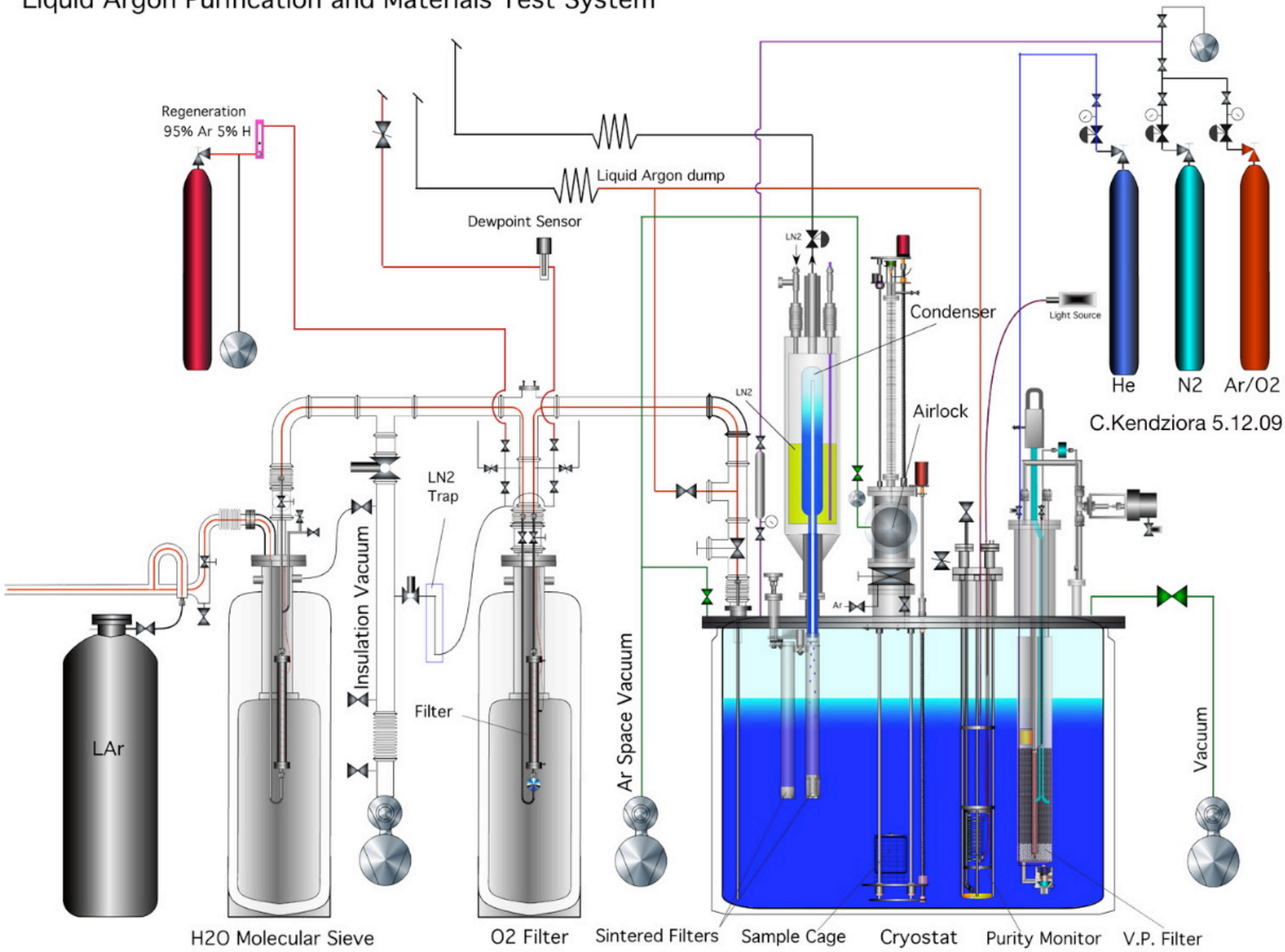
First thing to do – learn how to make (really) clean argon.

Key Lessons therein (Cary may elaborate).

High quality fittings (particularly valves), purges on all reliefs, making our own filters (that can be regenerated in place) that gives essential flexibility, bypass of final product before entry into cryostat, the use of both water (zeolite) and oxygen filters (?).


GON ARGON AR
DURA-CYL
180 HP
ARGON
REFRIGERATED LIQUID
UN 1951
LUKE
ARGON
REFRIGERATED LIQUID
UN 1951

Liquid Argon Purification and Materials Test System



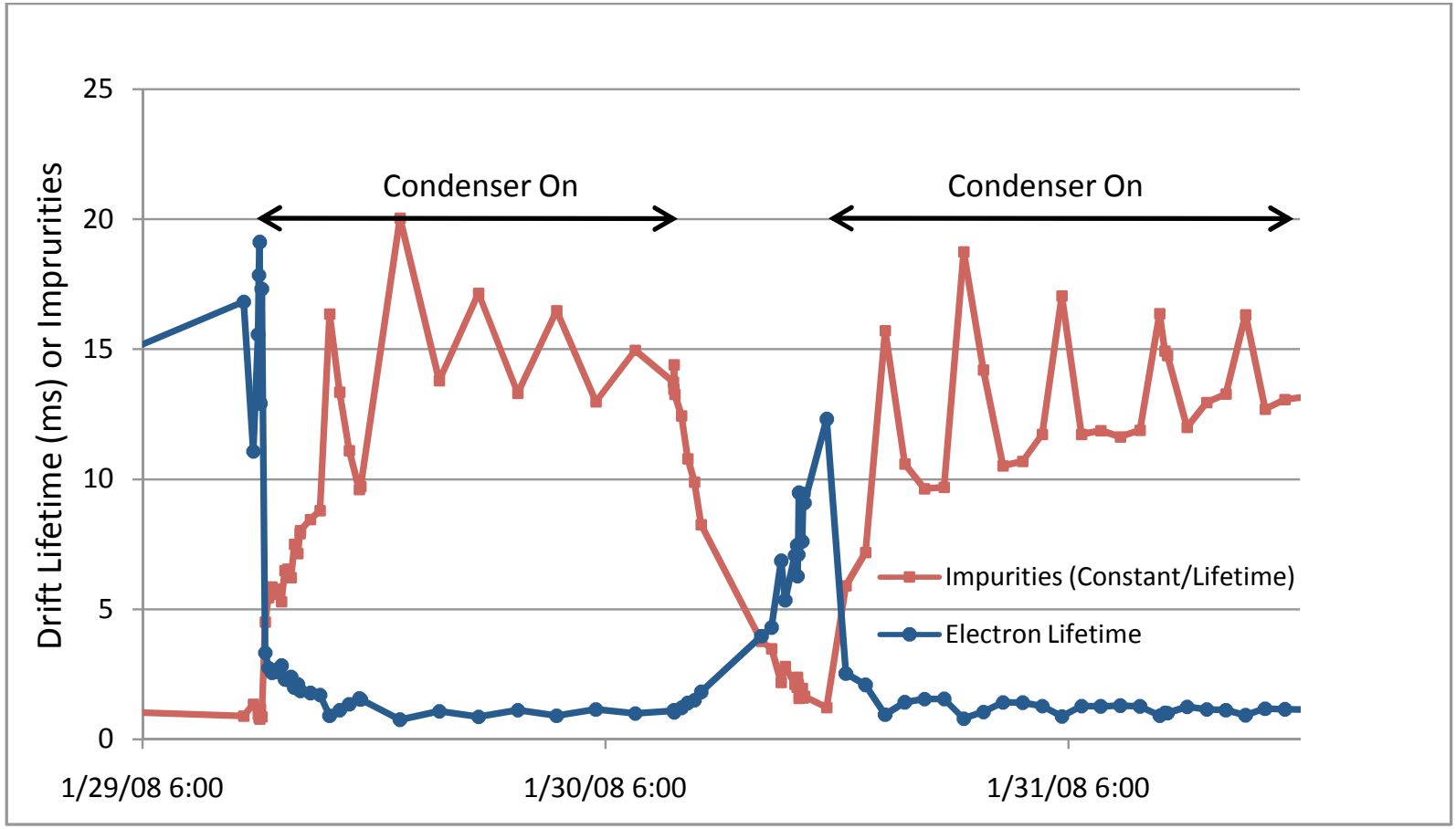
Features of Materials Test Stand

- Can insert materials into known clean argon
- Can insert materials after purging only or after pumping on them.
- Can position materials into liquid and into ullage with range of temperatures.
- Can insert known amounts of contaminant gases
- Nitrogen-based condenser can maintain liquid for long (weeks) studies
- Internal filter-pump can remove contamination introduced by materials – 2hr cycle
- Sample points at Argon Source, after single-pass filters, in cryostat gas and liquid

Measurement Features of Materials Test Stand

- Measure electron drift lifetime with ICARUS style purity monitor
- Measure Oxygen (0.3 ppb sensitivity) with oxygen meter (Delta-F & Tiger Optics)
- Measure H20 in gas (0.3 ppb sensitivity) with water meter (Tiger Optics)
- Cryogenic data, Lifetime Data, analytic instrumentation data in single data-base

In late 2008 we achieved > 10 millisecond lifetimes, but elation turned to despair when we turned on the condenser for the first time.



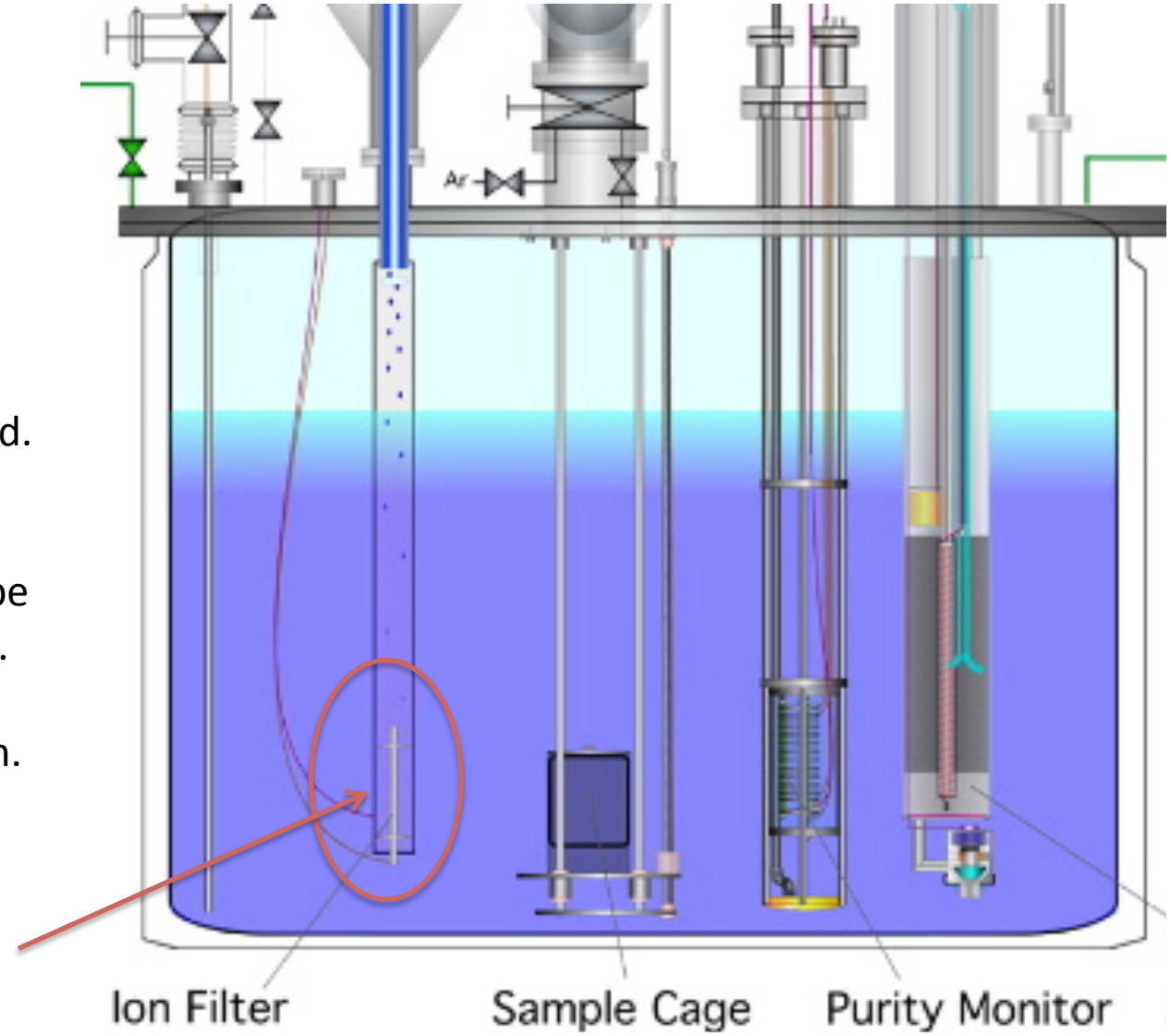
Test of Charged Ion Hypothesis

Ion hypothesis:

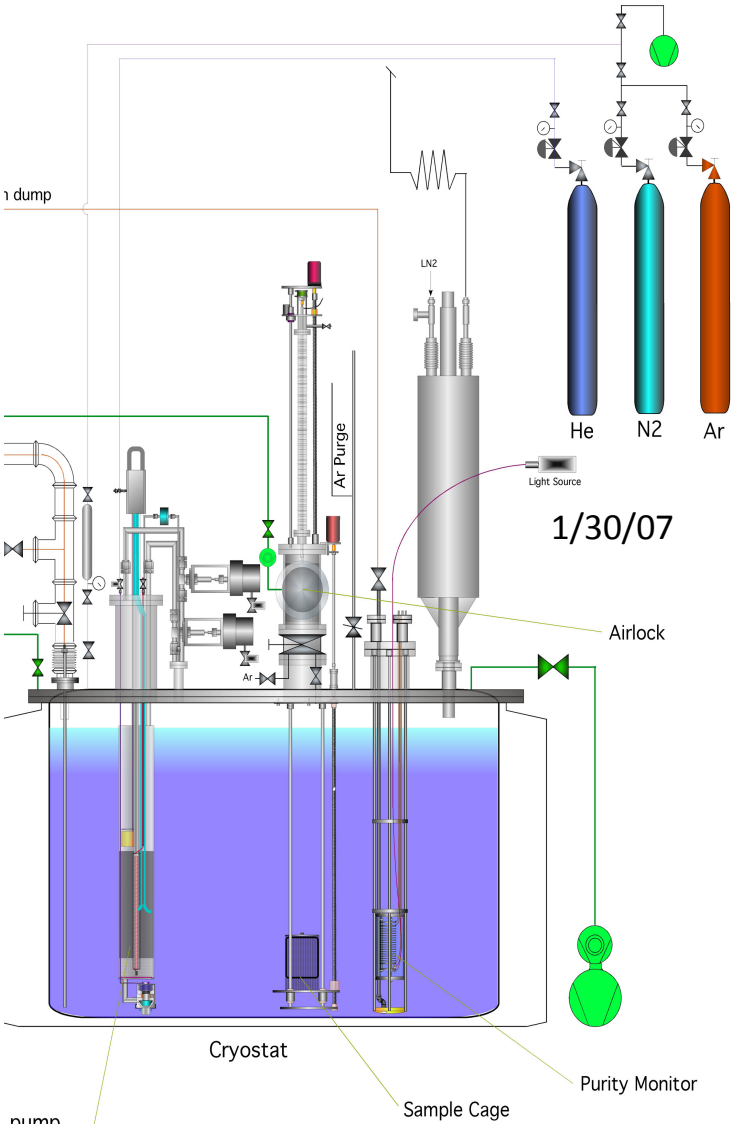
dripping was causing the Argon atoms to become charged.

1st test was to put steel wool at the end of the return pipe – the lifetime recovered.

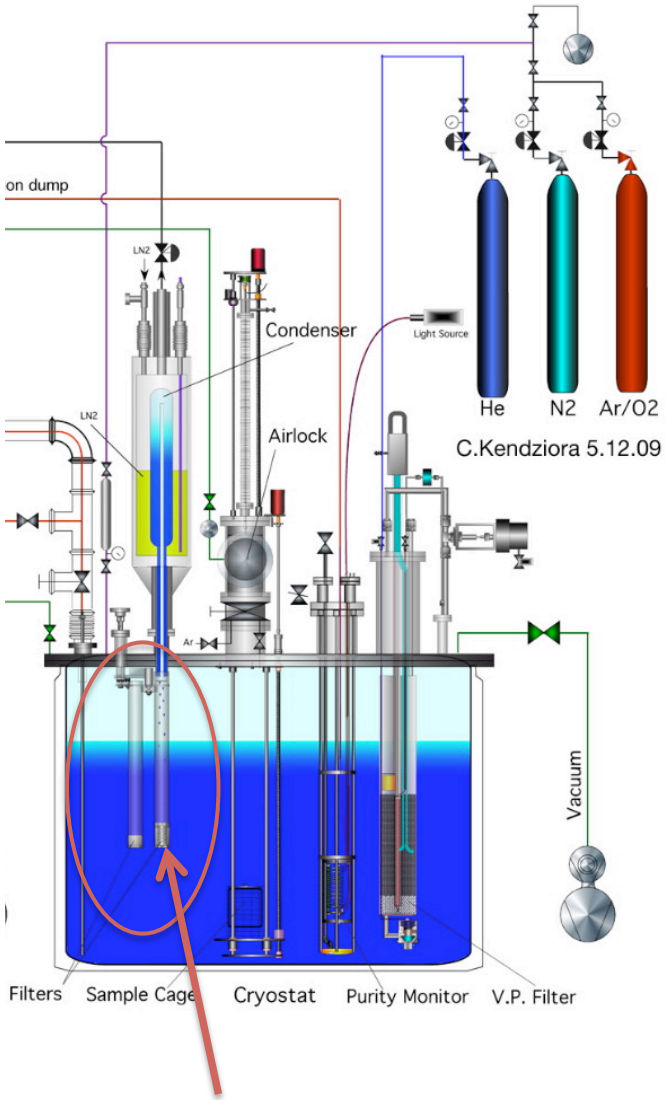
2nd test was to put a field in the return pipe to discharge the ions. That didn't work and we had to think again.



Original configuration



Present configuration



return filters key to operation with condenser

What was actually happening:

All warm surfaces (such as the uninsulated top of the cryostat, and the airlock) outgas water into the gas volume above the liquid (the ullage).

The condenser condenses this argon-water mixture and injects this mixture very effectively into the bulk-liquid – hence the deterioration of the lifetime.

Water in the liquid will plate out on the cold metal surfaces – hence the recovery of the lifetime.

Resolution: return liquid through sintered metal (1) containing zeolite (2);

Lessons of lessons for making clean argon in an (essentially) empty cryostat:

get a water meter - from Tiger Optics
minimize warm surfaces exposed to liquid;
avoid cold surfaces which can condense argon-water vapor mixture and return this mixture unfiltered to the bulk liquid;
metal (steel) is special; sintered metal removes water, sintered glass does not;
adequate boil-off will prevent water in ullage from entering the bulk liquid.
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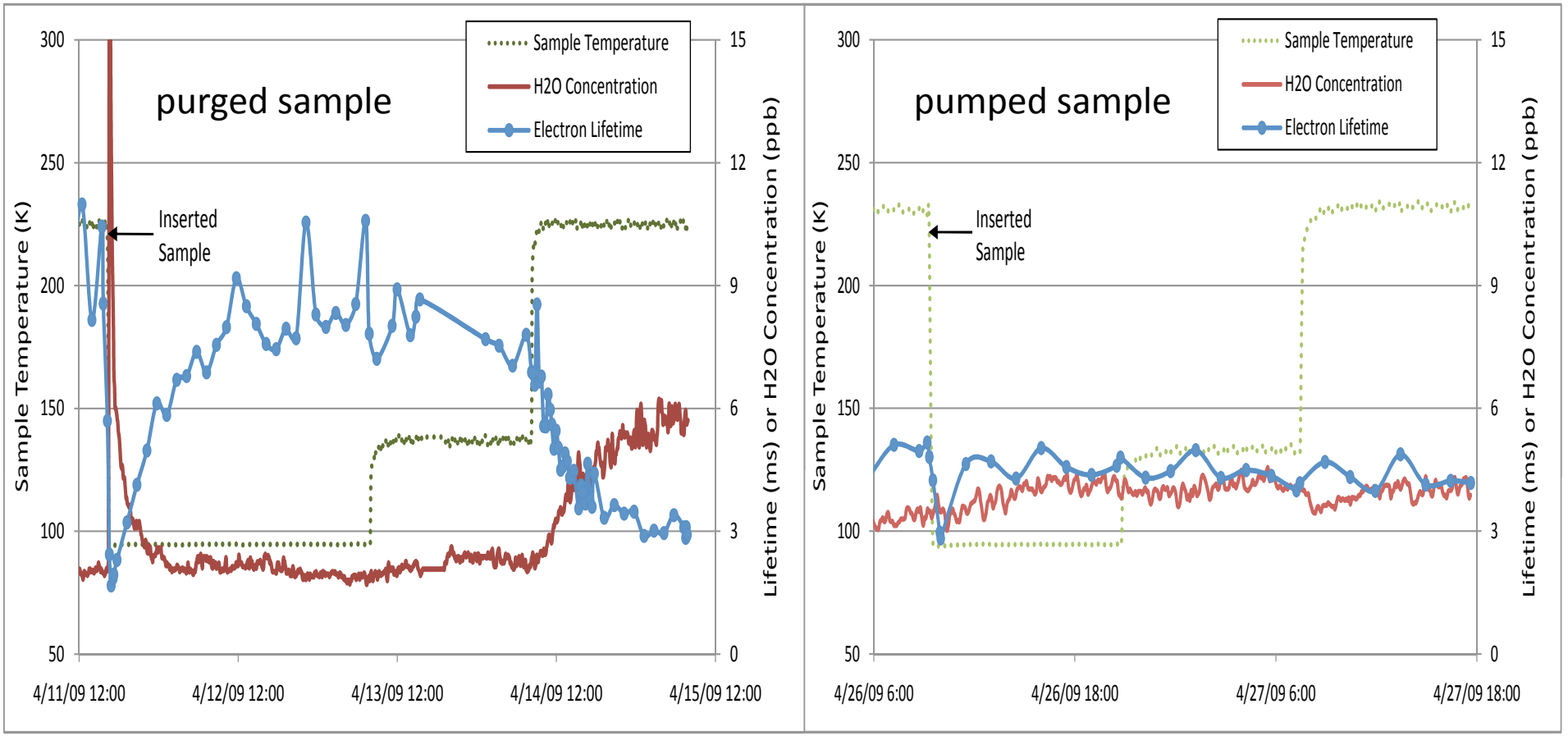
Bottom Lines in a closed system:

Materials in the liquid have no observed effect on lifetime;

Materials in the gas have an effect proportional to their water-outgassing rate and the fraction of that water that gets returned to the liquid;



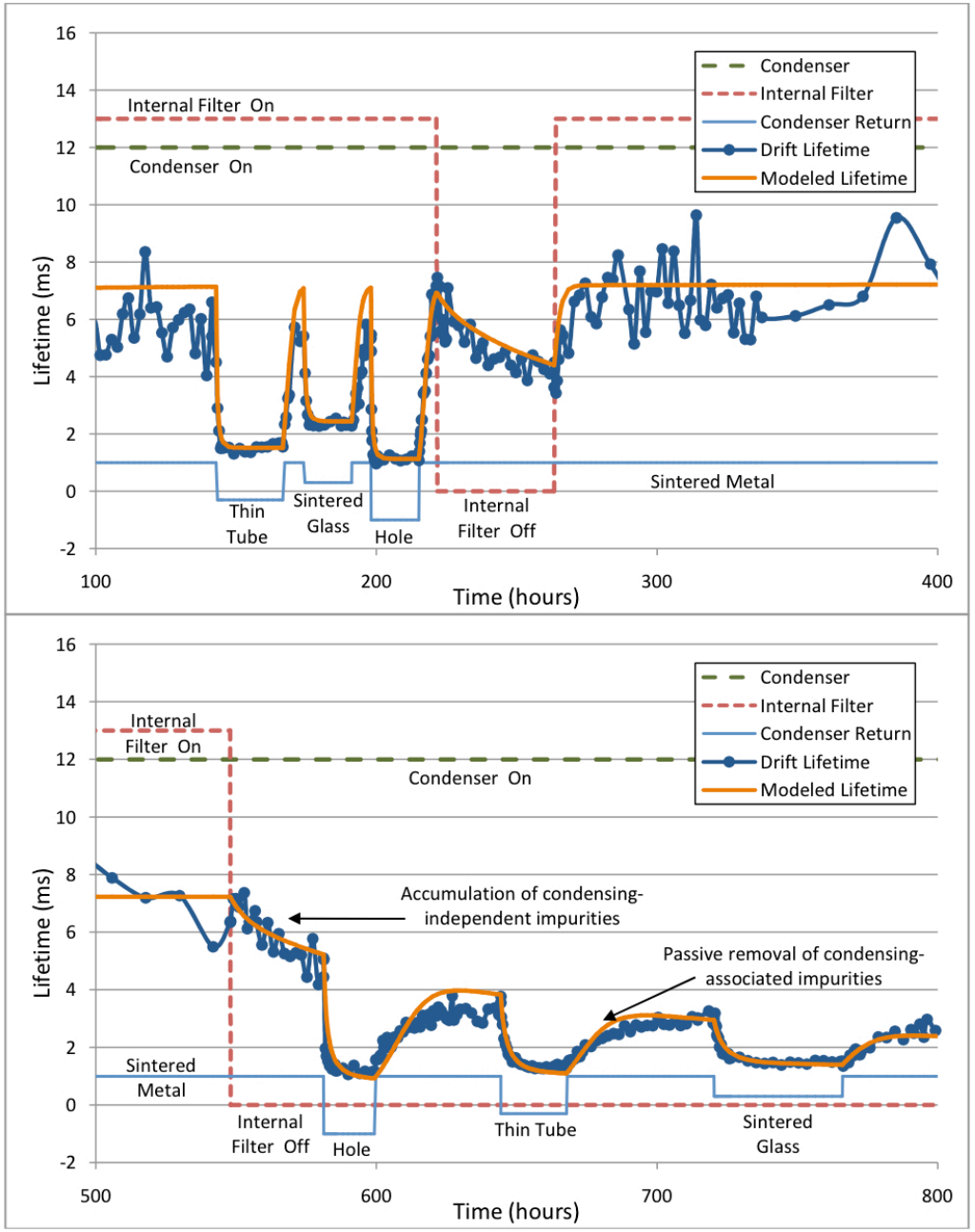
Effects of Materials

Material	Sample Surface Area (cm^2)	Effect of Material on Electron Drift Lifetime (LT)			Comments
		94 K liquid	≈120 K vapor	≈225 K Vapor	
Red-X Corona Dope[a]	100	None	None	LT Reduced from 8 to 1 ms; recovery observed.	H_2O concentration not monitored.
Deactivated Rosin Flux[b]	200	None	Not Tested	LT reduced from 8 to 1.5 ms recovery observed	H_2O concentration not monitored.
FR4	1000	None	Not Tested	LT reduced from 8 to <1 ms	Outgassed enough H_2O at 225 K to saturate sintered metal return.
Taconic[c]	600	None	Not Tested	LT reduced.	Sample outgases water at 225 K.
Hitachi BE 67G[d]	300	None	Not Tested	LT reduced; recovery observed	Sample outgases water at 225K; outgassing reduced over time.
TacPreg[e]	200	None	None	LT reduced; recovery observed	Sample outgases water at 225 K; outgassing reduced over time.
FR4, y-plane wire endpoint for uBooNE	225	None	None	LT reduced from 8 to 3 ms	Sample outgases water at 225 K.
FR4, y-plane wire endpoint for uBooNE	225	None	None	None	Sample was evacuated in airlock prior to testing
FR4, y-plane wire cover for uBooNE	225	None	None	None	Sample was evacuated in airlock prior to testing
Devcon 5-min epoxy	100	None	None	LT reduced from 10 to 6 ms; some recovery observed	Sample outgases water at 225 K.

– no effect on lifetime when material is in Liquid

It is possible to model effects of metal surfaces on lifetime

(see FN-09-355E)



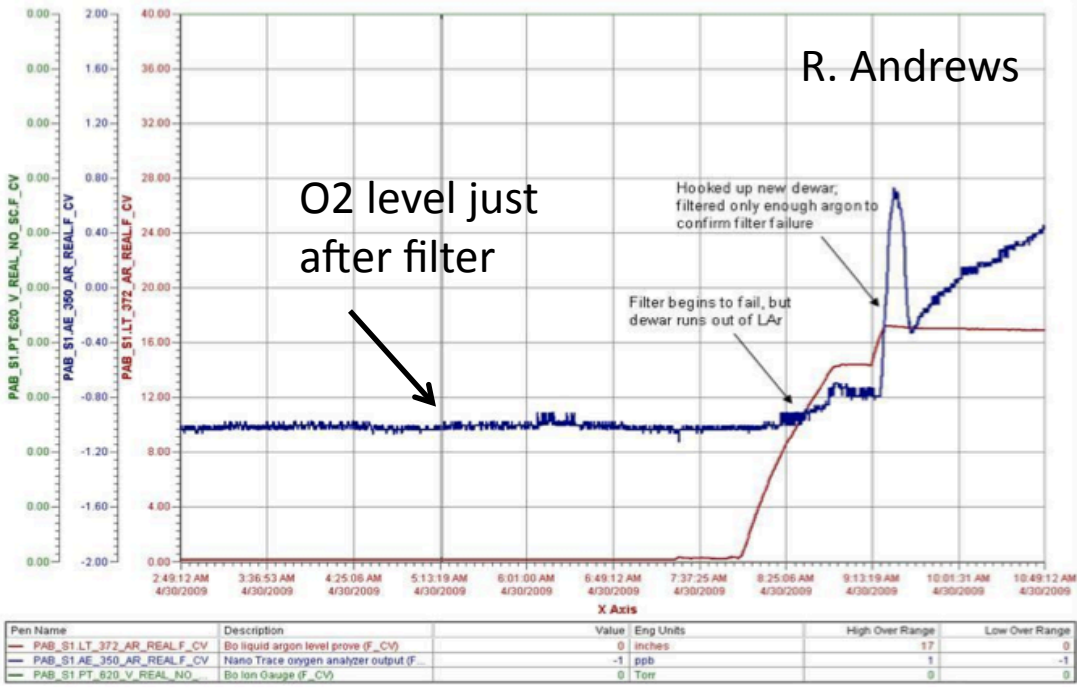
Filter Materials

We make (and regenerate) our own filters using material from BASF (originally Engelhard) for O2 and Molecular Sieve from Aldrich

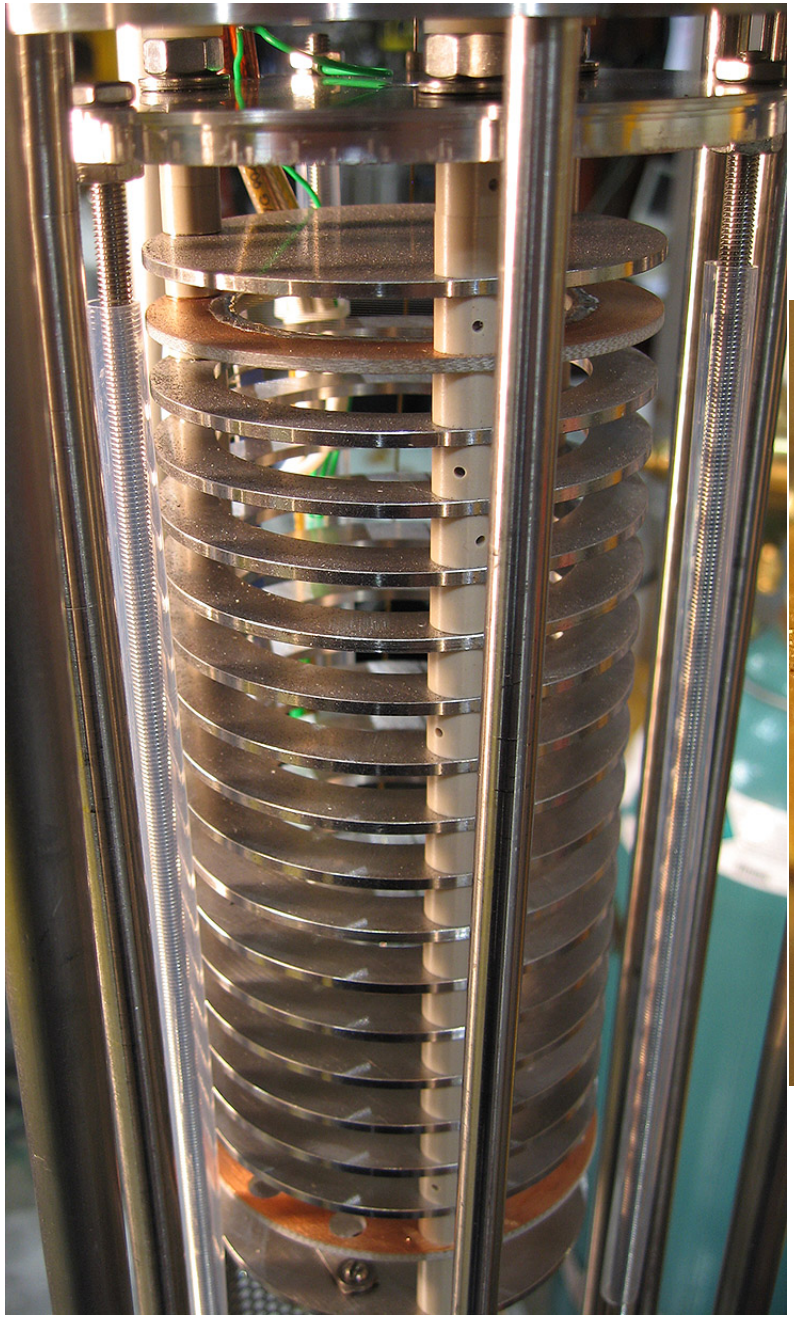
We have the capability to use other materials but have not pursued that – we need to

We are interested in the capacity of filter materials before `breakthrough' - the capacity is much less than one would calculate from the quoted area of copper.

Vendor data is not very useful – not at cryogenic temperatures and not at our sensitivity (1% inefficiency where we are interested in 0.001% inefficiency)

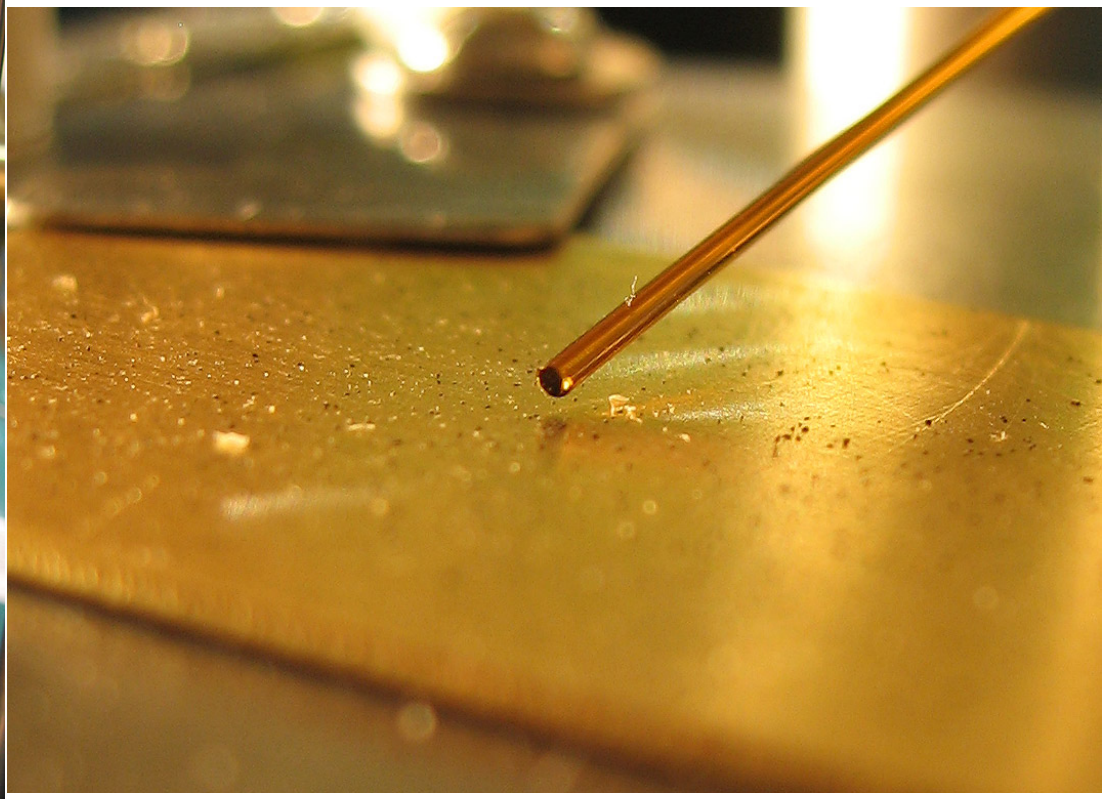


Plot of O2 level after ~ 0.5 g O2 through filter.
Note the `breakthrough' style of behavior.



purity monitor

Filters have some detritus – which seems to be affected by electric fields (more dust at higher voltage plates)



purity monitor photocathode and fiber – we keep the voltage off when not taking a reading.

Some purity Issues that need to be resolved that LAPD is not asked to answer:

Are there better (more cost effective) filter materials - we've been told there are

Can we model filter materials – the flow dependence as a particular example

Can we understand the ArgoNeuT experience in detail and apply that to MicroBooNE and LBNE.

How rapidly do materials reabsorb/readsorb water

How rapidly do materials desorb/outgas (we know the water content but the rate of outgassing is not typically available)